

Canada-B.C.

Conservation and Renewable Energy Demonstrations

B.C. 28



Energy, Mines and
Resources Canada
Conservation and
Renewable Energy Branch

Energie, Mines et
Ressources Canada
Bureau de la conservation
et des énergies renouvelable



Province of
British Columbia

Ministry of
Energy, Mines and
Petroleum Resources
CONSERVATION AND
TECHNOLOGY DIVISION

HAMMOND BAY GREENHOUSES
DEMONSTRATION PROJECT

Conservation and Renewable Energy Branch
Ministry of Energy, Mines and Petroleum Resources
Vancouver, B.C.

CANADA/BRITISH COLUMBIA CONSERVATION
AND RENEWABLE ENERGY DEMONSTRATION AGREEMENT

The availability of secure and affordable energy supplies is a subject of national concern. It is an accepted fact that our primary energy sources - oil and natural gas - are becoming less accessible and more costly. However, Canada is well-endowed with non-renewable and alternative resources that can provide a bridge into the future.

To this end, the government of British Columbia and Canada have entered into a Conservation and Renewable Energy Demonstration Agreement. The Agreement is dedicated to the development and demonstration of conservation and renewable technologies.

The objectives of CREDA are:

- o To develop and demonstrate promising new technologies, which, when widely adopted, will exploit renewable resources, conserve energy and/or use energy more efficiently.
- o To develop broad public awareness of the potential of renewable energy and conservation technology.
- o To provide opportunities for the commercial application of the technologies within B.C.
- o To create employment in new or existing energy-related industries.

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EXECUTIVE SUMMARY

The Hammond Bay Greenhouse Demonstration Project was an attempt to demonstrate an innovative commercial greenhouse heating system which had the potential to result in significant energy savings. The project was funded under the Canada/B.C. Conservation and Renewable Energy Demonstration Agreement (CREDA) and was initiated in 1980.

Hammond Bay Greenhouses is a commercial tomato greenhouse operation located near Nanaimo, B.C. The heating system being demonstrated consisted of circulating hot water heated by an oil fired boiler through steel piping within a plywood enclosure. As the potted tomato plants were suspended within this enclosure the growing medium was kept warm. This enabled the greenhouse air temperature to be lowered, thereby, reducing heat loss from the greenhouse.

Initial estimates of energy savings were in the order of 50% for the 25m x 62m greenhouse. However, operational changes since this estimate would suggest lower potential savings. Unfortunately, at the time of this report, no valid monitoring results were available due to monitoring equipment malfunction.

Tomato production with the innovative heating system, however, has been a pleasant surprise and has averaged 13% greater than production under the control heating system.

RÉSUMÉ DESTINÉ À LA HAUTE DIRECTION

Le Projet de démonstration des serres Hammond Bay avait pour but de démontrer les grandes économies d'énergie possibles grâce à un nouveau système de chauffage des serres commerciales. Ce projet, mis de l'avant en 1980, était financé dans le cadre de l'Accord Canada-Colombie-Britannique de démonstration des économies d'énergie et des énergies renouvelables.

Les serres Hammond Bay sont une exploitation commerciale servant à la culture des tomates et sont situées près de Nanaimo, en Colombie-Britannique. Le système de chauffage comprend un réseau de canalisations d'acier où circule de l'eau chauffée par une chaudière alimentée au mazout. Ces canalisations se trouvent à l'intérieur d'enceintes de contre-plaqué. Comme les pots contenant les plants de tomates sont suspendus à l'intérieur de ces enceintes, les plants peuvent croître dans un milieu chaud. Ainsi, la température à l'intérieur de la serre peut être abaissée, ce qui permet de réduire les déperditions de chaleur.

Selon les estimations initiales, les économies d'énergie sont de l'ordre de 50 % dans une serre de 25 m sur 62 m. Toutefois, des changements apportés depuis les dernières estimations pourraient diminuer le potentiel d'économie d'énergie. Malheureusement, au moment de la rédaction de ce rapport, il a été impossible d'obtenir des résultats de contrôle valables, à cause d'un mauvais fonctionnement des appareils de contrôle.

Surprise agréable, grâce à ce système de chauffage, la production de tomates a augmenté d'environ 13 % par rapport à celle obtenue avec l'ancien système de chauffage.

1. INTRODUCTION

The greenhouse industry is one of the most energy intensive areas in the agricultural sector with energy costs accounting for up to 40% of total production costs. This figure represents a significant increase over other production costs. For example, energy costs of cucumber production rose from 12% of production costs in 1975 to 39% in 1983 under natural gas heating. Greenhouse operators faced with oil heating bills (as found on Vancouver Island) pay a significantly greater share of operating costing towards heating.

The Hammond Bay Greenhouse Demonstration Project which has been funded through the joint B.C./Canada Conservation and Renewable Energy Demonstration Agreement (CREDA) is an attempt to demonstrate an innovative greenhouse heating system which is expected to result in significant energy savings. If proven successful, the energy savings could make many existing marginal greenhouses viable.

Hammond Bay Greenhouses is a commercial tomato greenhouse operation which is located approximately 20 km north of Nanaimo. In the experimental greenhouse, the growing medium is kept warm which allows the air temperature to be kept lower than normal. As a result of the lower air temperature heat loss from the greenhouse envelope is expected to be reduced. Initial estimates of energy savings were in the order to 50%.

2. BACKGROUND

The project was initiated with a proposal from the proponent Peter Maurer, proprietor of Hammond Bay Greenhouses in August 1980. The new heating installation was completed and the first tomato crop was in place by November 1980. At the time of this report, the system had been in operation for approximately three years.

The objectives of this project were to demonstrate and monitor an innovative commercial greenhouse heating system and to provide this information to the public. Adoption of this system in other commercial tomato greenhouses would allow local growers to retain a competitive edge against imports, and would contribute to greater self-sufficiency in meeting energy needs as well as in food production.

The total budget for the project was \$31,300 of which \$18,000 was contributed through CREDA. The remaining \$13,300 was provided by Hammond Bay Greenhouses. Out of the total budget \$5000 was set aside for information transfer and monitoring. The installed cost of the system totalled \$26,300. This included the piping and controls required to distribute hot water through the 1554 square meter greenhouse but did not include the existing oil-fired boiler.

Supervision of the system installation was carried out by Peter Maurer. The Conservation and Renewable Energy Branch of the B.C. Ministry of Energy, Mines and Petroleum Resources provided the contract administration and helped to establish the monitoring program.

3. SYSTEM DESIGN

3.1 Requirements for Performance Comparison

In order to evaluate the energy saving potential of the heating system, there was a requirement to have a control which did not use the innovative heating system to make comparisons. To accomplish this, a 25 m x 62.2 m gutter connected greenhouse was divided with a sheet of polyethelene running along its length forming two halves of dimensions 12.5 m x 62.2 m each running along a north-south axis. Although this does not provide complete isolation under identical conditions between the two halves, it was the best that could be achieved with the existing available greenhouses.

Each half of the greenhouse had a separately controlled air heating system but shared a commonly controlled growing medium heating system. In the experimental half, the growing medium heating system was operated to maintain the growing medium at a pre-determined temperature. The setpoint of the air heating system was maintained at a lower temperature than normal for tomato production. The control half was operated conventionally by maintaining the air temperature at the normal temperature range for the crop. The growing medium heating system was valved off.

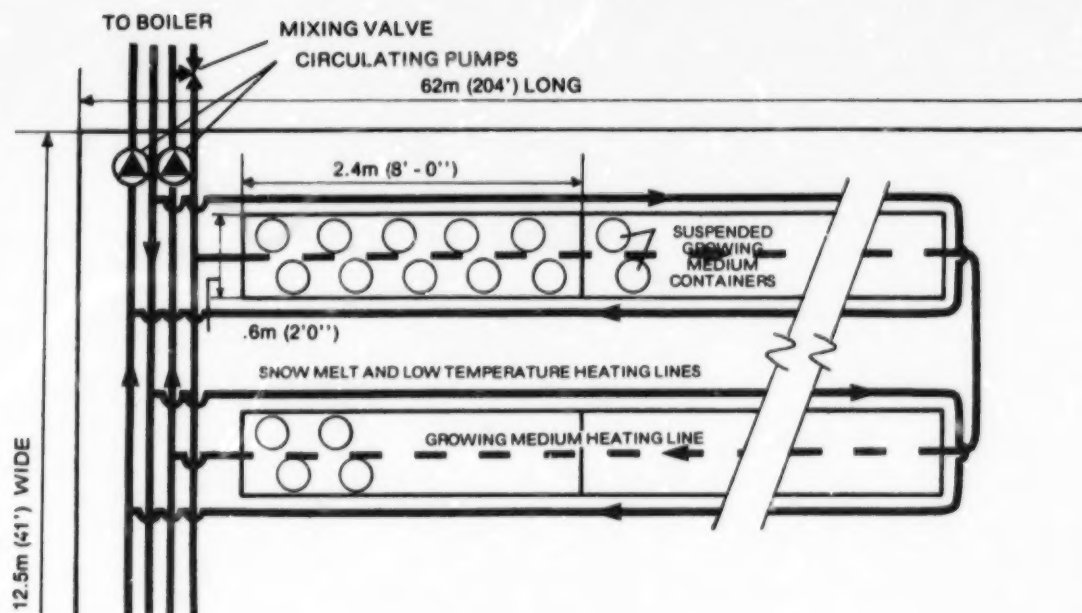
3.2. Technical Details

As previously mentioned the greenhouse heating system consisted of three hot water 50 mm diameter steel piping circuits. One was used to heat the growing medium while the other two heated the air in each greenhouse half and was occasionally used for snow melt control. Water in all circuits was heated by a single 98.1 kW (100 HP) 4 pass oil fired boiler. However, each circuit was independently controlled by a thermostat which cycled a 250 W (1/4 HP) circulating pump. The thermostat for the air heating system in each greenhouse half was suspended centrally within its respective half. The thermostat controlling the growing medium temperature was located within the enclosure in which the tomato pots were suspended. The thermostats are low voltage (24V) thermostats which activate a relay thereby energizing the appropriate circulating pump when heat is required.

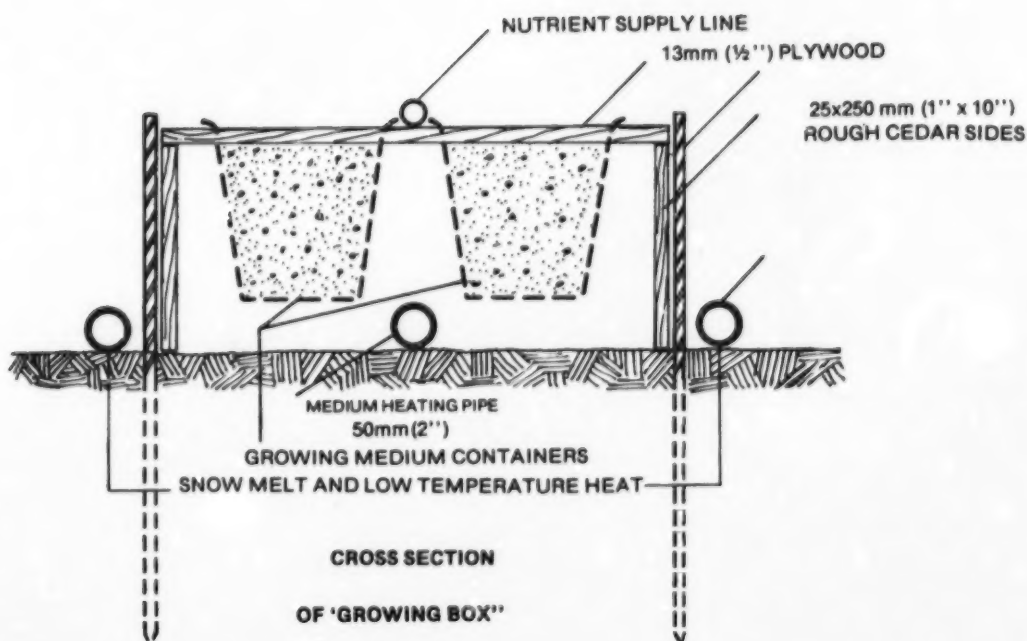
Hot water leaves the boiler and enters the greenhouse at between 83°C and 92°C (lower and upper limits). This water is circulated through the air heating system directly. Hot water entering the growing medium heating systems, however, first enters an automatic mixing valve where return water from the system is mixed to supply 60°C hot water. Figure 1 illustrates the piping layout for the system.

The enclosure or "growing box" in which the potted tomato plants are suspended is illustrated in cross section in Figure 2. The enclosure is constructed of 25 x 250 mm rough cedar along the sides and 13 mm plywood along the top. Circular holes cut out of the plywood top provide a means to suspend the potted tomato plants. The enclosure is supported by 13 mm reinforcing bars driven into the ground. The tomato plants are fed a nutrient solution.

The growing box provides several advantages. For one, it offers an enclosure which helps to keep the heat in maintaining a relatively warm growing medium temperature. Also, it supports the tomato plants above the ground which reduces the susceptibility of transmitted disease between plants.



GREENHOUSE LAYOUT



4. SYSTEM OPERATION

Originally, the intention was to allow the air temperature in the experimental portion of the greenhouse to drop to 11°C (52°F) while maintaining the growing medium at a minimum of 18°C (65°F). However, it was found that tomato production was adversely affected at this air temperature. The tomato plants grew vigorously, were dark green and had many flowers. However, after the flowers dropped off there were thousands of cherry sized tomatoes which remained this size until maturity.

After discussions with Brian Mauza, a greenhouse specialist with the B.C. Ministry of Agriculture and Food, it was learnt that the probable cause for this condition was the low air temperature which resulted in non-viable pollen. Non-viable pollen allows fruit to set but does not allow seed formation resulting in abnormally small tomatoes.

After this experience, the following procedure was adopted for the 1983 spring crop.

- December 29 - Seeds were started in the propagation
(1982) greenhouse at about 24°C (75°F) in very small pots called jiffy pots. Each pot received only one seed.
- January 3 - The first seeds had germinated. The
(1983) temperature was reduced to 21°C (70°F).
- January 4 - Mercury vapour and sodium lamps were turned on
for 14 hours per day to make up for poor daylight conditions. The propagation greenhouse temperature was further reduced to 17-18°C (62-65°F).
- January 17 - The tomato plants were now ready to be planted
in their final position and were moved from the propagation greenhouse and into the experimental greenhouse. Both the experimental greenhouse half and the control half were maintained at 17-18°C (62-65°F).
- March 5 - At this point, the air temperature in the
experimental half was lowered 0.5°C per day until 11°C (52°F) was reached. In terms of the stage of plant development, this temperature lowering occurred after development of the third fruit truss on the tomato plant.

- April 18 - By this date, it was evident that the experimental half was not producing as many tomatoes, but the tomatoes were much larger.
- May 18 - The control half had been out-producing the experimental half to this point. However, at this point this trend was reversed.
- July 12 - The crop is finished. The experimental half produced 13% more cases of tomatoes than the control half.

Increased production in the experimental half was generally consistent with few exceptions caused by initial improper setpoint temperatures and mechanical failures. The following table tabulates the crop production of the control and the experimental half of the greenhouse.

<u>Crop</u>	<u>Control (lb)</u>	<u>(kg)</u>	<u>Experimental (lb)</u>	<u>(kg)</u>
1981 Spring	-		No crop	
1981 Fall	No data		No data	
1982 Spring	18,840	(8,564)	21,280	(9,673)
1982 Fall	13,460	(6,118)	14,740	(6,700)
1983 Spring	18,460	(8,391)	21,440	(9,745)
1983 Fall	9,820	(4,464)	8,920	(4,055)

As previously mentioned, the 1981 experimental spring crop failed because of temperatures too low for viable pollen formation. The 1983 fall crop showed tomato production to be greater with the control crop than with the experimental crop. However, the figures are misleading since the crop was terminated two or three weeks earlier than normal due to failure of the boiler. Had it not been necessary to terminate the crop early, it is likely that the experimental crop would have outperformed the control crop as the experimental crop generally performs relatively slowly initially but more than makes up for this during the latter stages of the ~~crop~~ growth.

Other mechanical problems which arose included the malfunctioning of the mixing valve and the development of leaks in the piping system. The mixing valve was subsequently operated manually to maintain the growing medium heating system at 60°C until repairs could be made. Major leaks in the piping were repaired. Leaks of a minor nature seem to be still evident since the boiler water level requires occasional topping-up.

5. MONITORING

The original monitoring system installed by the project proponent consisted of electrical clocks which were activated individually whenever the corresponding circulating pump was on. By resetting the clocks to zero, it was possible to measure and compare the lapsed operating time of the circulating pumps for the two halves of the greenhouse over any time period. This system was considered to be inadequate since its validity is based on the assumption that pump operating time is directly proportional to energy consumption and that this proportionality is constant across the three separate circulating pumps and piping circuits in question. This assumption is unlikely to be correct since there are different pipe diameters, piping lengths and pump sizes involved.

To measure the energy consumption of each greenhouse half directly, flowmeters were installed to measure the cumulative hot water flow in each circuit. Temperature gauges were installed on the supply and return of each piping circuit in order to measure the hot water temperature drop within the greenhouse. Knowing the volume of water that has passed through the greenhouse and the temperature drop it has undergone, it becomes a seemingly simple task to calculate the amount of heat released to the greenhouse by each piping circuit.

However, it became apparent that monitoring the greenhouse by this method was not practical. The problem was in measuring the temperature drop between the supply temperature and the return temperature. There was a time lag of approximately 15 minutes from the time the circulation pump began circulating hot water and the time the supply header became warm. Also, cycling of the boiler caused the supply temperature to fluctuate between the lower and upper setpoints. Ideally, one would want to measure the temperature of a plug of water as it passes the supply and return temperature gauges. This was not possible due to the time lag and temperature fluctuations.

Given enough time, one could continuously and simultaneously measure the hot water supply and return temperatures over a period of time, possibly several hours, and record the fluctuating temperatures. The mean temperature difference over the measured time period would then be the difference between mean supply and return temperatures. One could possibly carry out this procedure monthly to observe any changes in the temperature difference as ambient air temperature change.

As this was anticipated to be a relatively time consuming procedure, it was decided to automate the taking of temperature readings through the use of three Campbell Scientific CR21 microloggers. Each micrologger was designated to record the supply and return temperature of each piping circuit via surface mounted thermistor probes (Campbell Scientific Model 102). The probes were attached to the pipe surface and were then covered with pipe insulation.

In order to conserve memory space and extend the time interval between site visits to dump data from the micrologger, the micrologger was programmed in such a way that it only recorded data when the circulating pump was operating. This was accomplished by a relay which was energized when the circulating pump was in operation closing the relay contacts. The closed relay contact allowed a five volt signal to be received by the micrologger which signaled it to begin recording temperatures.

Although the micrologger takes sensor readings every minute, it was possible to have the readings averaged over a specified time period before being stored in final storage. It was thought that a time period of 30 minutes would not unduly erode accuracy and would allow the frequency of site visits to be manageable.

The programs used in the microloggers can be found in the Appendix.

Temperature measurement was not the only problem with the monitoring system. The flowmeters also caused problems as they kept breaking down. Apparently, corrosion of the steel pipe caused the flowmeters to foul up. In an attempt to alleviate this problem, an in-line strainer was installed upstream of each flowmeter. This proved unsuccessful, as the flowmeters continued to malfunction. Unfortunately, this represents the state of the flowmeters at the time of writing this report. All monitoring equipment is currently in place but may require repair or modification for continued monitoring. The greenhouse operator is currently investigating the use of plastic piping as a means of eliminating pipe corrosion.

6. RESULTS

Although the heating distribution system itself has been operating relatively successfully (based on reliability, crop production, and perceived energy savings by greenhouse operator) for three years now, no valid data has yet been gathered to document energy savings by the experimental heating system to allow conclusions to be drawn.

From the point of view of crop production, however, the system has demonstrated significant results. This was quite unexpected since one normally associates the lowering of greenhouse temperature at the expense of optimal crop performance. In order to verify that the improved crop production was in fact, due to the heating system and not some other extraneous factor, the control and experimental halves of the greenhouse were switched around by the opening and closing of valves. The half which was originally heated solely by the air heating system was now heated primarily by the growing medium heating system and vice versa. The new experimental half still maintained a productive edge over the control half.

The commercialization potential for this technology is relatively high provided useful data can be gathered to show that this system does in fact save sufficient energy to justify its cost. Other factors which make commercialization potential high is the fact that only existing standard components are required and no new skills need to be developed for its construction. Commercialization would provide further refinements to the system, reducing costs and potentially increasing efficiency.

Even in the absence of commercialization, there is still potential for widespread adoption by other commercial tomato growers. The systems's inherent simplicity would allow individual greenhouse operators to install their own systems.

7. RECOMMENDATIONS FOR PROJECT CONTINUATION

In order to assess the economic viability of this system, it is recommended that further attempts be made to measure the performance of the system. The following items should be considered.

- 1) In an attempt to reduce flowmeter fouling, hot water should be released from the boiler (blowdown) each day by quickly opening and closing valves located at low points near the boiler to help flush out accumulated mud and scale. Water treatment should also be considered to reduce corrosion and scaling. Measures to control scaling and corrosion will not only reduce flowmeter fouling problems but will also increase the efficiency and longevity of the boiler and distribution system.
- 2) The possibility of installing a separate boiler so that the fuel consumption of each greenhouse half is isolated should be investigated. This method would provide a direct measure of fuel consumption in each greenhouse half but should only be considered after water treatment and blowdown have been investigated due to the high cost and the resulting overcapacity of this option. The existing boiler can currently meet the total heating load of the entire greenhouse operation.
- 3) Currently the two halves of the greenhouse are separated by a polyethylene sheet which does not provide complete thermal isolation. The problem is compounded by the fact the poly sheet does not form a complete seal between the two halves due to gaps and openings in the poly. An attempt should be made to seal these openings as much as practically possible.

As there is currently no valid measured results of energy savings, information transfer has been limited. A project summary sheet has been created and a press release made. A tour for interested greenhouse operators in conjunction with other operations in the area with innovative energy conserving greenhouses was originally contemplated. This, however, was felt to be premature without monitoring results. In the event the project is continued and monitoring results are obtained, it is recommended that such a tour be considered.

An advance of \$3,540 has been made to the greenhouse proprietor solely for the purpose of information transfer. It was necessary to pay this in advance in order to release the funds to the project before the contract between Hammond Bay Greenhouses and the Ministry expired. Therefore, any future information transfer plans could draw from these funds.

APPENDIX

INPUT PROCESSING TABLE

*4	- Input Processing Table
1	
A	
10	- Supply Temperature Sensor (Channel 1)
A	(°F)
1D8	
A	
32	
A	
2	
A	
10	- Return Temperature Sensor (Channel 2)
A	(°F)
1D8	
A	
32	
A	

OUTPUT PROCESSING TABLE

*1	- Output Processing Table 1
A	
1440	
A	
62	
A	
7777	- Fixed to Number (Allows date to be shown when accessing data via display)
A	
0	
A	
65	
A	
30	- Conditional Output (Averaged over 30 minutes)
A	
4	
A	
51	- Average Supply Temperature (Channel 1)
A	
1	
A	
51	- Average Return Temperature (Channel 2)
A	
2	
A	